RESEARCH TOPIC REVIEW: Strategies for enhancing organic food quality

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1. Scope and Objectives of the Research Topic Review

This Research Topic Review aims to summarise the available knowledge on strategies for enhancing organic food quality. The Review will provide organic advisers with a better understanding of the differences between organic and conventional food quality so that they can support the development of organic farming systems and supply chains that deliver better quality organic food. The Review takes a broad definition of food quality and on the appropriate methods for determining food quality. However, the focus is on the factors that are more or less within the control of the farmer and the rest of the supply chain, and that directly impact on the appreciation or the intrinsic quality of the food as presented to, and eaten by the consumer.

The specific issues addressed by the Review (Section 2) include:

- Consumer perceptions of organic food qualities and the market for organic food
- Organic supply chains and their impact on quality, in the broadest sense
- Environmental quality of systems – although not an intrinsic quality (in the same way as, for example, the vitamin content of food), it is an important quality parameter for organic food
- Food safety
- Crop products – production systems and quality
- Livestock products – production systems and quality

Twenty three Defra funded research projects are reviewed and a total of 355 papers selected from the Orgprints archive (www.orgprints.org) using the search term "organic food quality" have been scanned. Thirty one have been selected for review. Several additional sources have also been identified. In total, 75 sources have been reviewed.

2. Summary of Research Projects and Results

2.1 Consumer perception of organic food qualities and the market for organic food

Fearne (2008) provides recent information, based on consumer research of 12m UK households over a two-years period, on the perception of quality, value and demand of consumers of organic fresh fruit and vegetable produce. The research found that only 16% of shoppers were driven by cost when buying organic fruit and vegetables, while key factors influencing purchasers were health, safety and taste. Fearne suggests that producers deepen their understanding of their customer base and develop better-tasting produce. Fearne highlights that, while organic fruit and vegetable prices have actually fallen in the year to January 2008, only 62% of those who bought organic fruit and vegetable produce repeatedly bought them, suggesting that unfulfilled promises of taste delivery were responsible for the low repeat rate. Developing better tasting products, not cheaper one, was more in line with organic fruit and vegetable consumers' expectations, he concludes.

Brennan et al (2002) found that consumer attitudes to foods are mainly influenced by quality attributes. Ethical factors are important in some cases, but they may be overstated. The relationships between consumers' awareness of organic food, price and perceived quality of food were investigated by tests involving series of consumer panels and sensory evaluation. Sensory responses were also matched to instrumental analysis data. Results indicated that overall there was no relation between panelist's views about organic foods and their sensory perceptions. Eighty percent of the panelists felt that organic products

were too expensive, but would buy them if they were cheaper. However the study showed that most of the people would not be likely to change their preference once they had made a product choice based upon sensory attributes. This has important implications, indicating that not only price, but also sensory quality of organic food must be considered in order to maintain repeated purchases by most consumers.

Brandt et al (2003) look at the large number of studies analysing the effect on human health of food produced according to organic standards compared with conventionally produced food. While many studies support a few general trends of differences in food composition, none have provided any conclusive evidence for differences in the effects on human health. Brand et al report on a study in progress, which comprises controlled cultivation of plants in three different models of growing systems for two years, and feeding rats for three generations on diets based on these plants. It will show if food from different growing systems can result in differences in health of rats, and if so, which aspects of health are affected. If the findings can be translated to human health, it is suggested that these could influence both the demand for organic food and lead to changes in farming methods in both organic or conventional production systems.

Ravn et al (2004) report on the increasing focus on the quality and health value of organic plant products compared with conventional products. The use of pesticides and concentrated fertilisers in conventional agriculture implies a risk of effects on plant composition, which may affect health of the consumer (Brandt & Mølgaard, 2001). To determine if organically grown plant food could provide more or less benefits to health than conventional food, a first step is to investigate the differences in the composition and relative concentration of natural compounds in the plant products. In this project apples were grown with two levels of nitrogen availability and with or without the use of pesticides. The apples were screened for changes in the phytochemical composition and concentration. The work is affiliated to the project "Organic food and health" supported by the Danish Research Centre for Organic Farming (DARCOF). Biomarkers and biomarker patterns were presented in plants cultivated with low and high N and with pesticides.

Bodini et al (2006) analyse the reasons why the key market segment of occasional organic purchasers do not purchase more organic food. Occasional buyers tend to take a more critical view of organic food and the organic farming concept in general, and the main barrier preventing this group from expanding its consumption of organic food is the higher price, which, in their perception, is not justified sufficiently by added quality attributes. Consequently, to encourage a greater purchase by this market segrment, it is important to communicate the key quality attributes of organic food and to use producers to promote their food more directly.

Noe and Alroe (2007) reflect on the link between the organic food supply chain and the quality of the food produced, they present a theoretical and analytical framework and tool to examine how the values of organic food are mediated between producers and consumers, and how this is linked to the way the food chain is constructed, who is involved, and the way the market is developed. They suggest that the quality of organic food is linked to the entire production and processing chain and analyse three different Danish organic supply chains. They conclude that, from an organic farming perspective organic farmers should not only focus on the quality of the products and their way of farming, but also on how these qualities can be processed, carried and communicated throughout the whole food chain to the consumers.

2.2 Organic supply chains

Stolze et al (2007) explore the potential for improving the link between supply chain performance and possible performance improvement with respect to food quality and safety. They conclude that better collaborative planning and closer supply chain relationships could help improve quality and safety of organic supply chains. A component of this is the origin and provenance of the organic food, Beck et al (2007) propose that the “quality of origin” of organic ingredients should be clearly communicated to consumers to support the link that is made throughout he supply chain.

Ongoing research by Warwick HRI (HRI, 2007) into the market for organic food in the UK aims to characterise the market in terms of its operation to identify opportunities and constraints and market sector linkages. Through targeted case studies, the reasons for success and failure in the market will be determined and the economic barriers to market development evaluated. Finally the socio-economic challenges and barriers to market penetration and development will be assessed.

Value chain analysis can provide useful insight into the costs and quality impacts of each stage of the supply chain. This concept has been applied to organic produce supply chains (Cardiff University, 2006), for organic carrots, potatoes and lamb. The approach can help enhance quality by improving understanding of various process steps in the supply chain.

2.3 Environmental quality of systems

The environmental quality of organic production systems is measured in terms of biodiversity and habitat; pollution; resource use and so on. Numerous reviews have concluded that, overall, there is a positive environmental impact arising from organic production, although this is not always the case. This review is primarily concerned with the intrinsic quality of organic food, and thus a review of environmental impacts is not included. However, it is acknowledged that there are a wide range of organic systems, managed more or less well from the point of view of environmental protection or enhancement. Consequently from this perspective, the extrinsic quality of organic food in terms of the environmental impact of the production system will vary widely. Consumers expect that organic production is associated with environmental protection and enhancement, this is a feature of organic standards. However, the extent to which this expectation is matched by reality depends on the environment quality of the system (throughout the whole supply chain, from 'farm to fork'. Both farmers and advisers can influence the environmental quality of the system and the use of whole farm conservation planning and environmental management tools are central to progressive development at the farm level.

A Defra funded project on environmental benchmarking of organic agriculture explored the potential for the development of a benchmarking tool for use by farmers and advisors (ORC, 2007). The benchmarking tool was developed and tested on several organic farms. It was concluded that although benchmarking is a very important tool to enable improvement in the environmental quality of organic systems, there are considerable difficulties in implementation. Notably there is a lack of high quality and robust standard reference data, and there are significant difficulties in the collection and recording of relevant information at farm level. Farmer record keeping is required for the monitoring or evaluation of the farm by someone other than the farmer, and is often not seen as beneficial or positive. However, if suitable and easy methods to collect data could be devised, then benchmarking would be possible and could improve the environmental performance of organic farms.

2.4 Impact of GMOs

Organic standards specifically prohibit the use of genetically modified organisms (GMOs) and do not permit the presence of the products of GM in organic food and livestock feed. The new EU organic regulation (EC 834/07) sets limits for adventitious contamination of organic products by GM, although these are contested by the organic sector, with many organic stakeholders considering that it will be increasingly difficult to maintain the GM-free status of organic products. The prohibition of GM in organic systems, and thus the presumed GM-free status of organic products is a key quality feature, based on values and principles concerning the integrity of life and the unacceptability of 'interfering' with living processes in the way that is implied in genetic modification of organisms. However, this value based perspective is underpinned by the precautionary principle and a presumption of an intrinsic potential hazard arising from the use of GM. The

evidence of harm to the environment, or human and animal health arising from the use of GM is contested, as is the potential benefit from use. Risk assessment can allow the likelihood of harm to be quantified, however, there are inherent difficulties in completing a risk assessment for GM, which justifies precautionary stance of the organic sector.

The potential impact of GMOs on organic agriculture has been reviewed in a Defra funded project by John Innes Centre and Organic Research Centre Elm Farm (Innes, 2002). The aim of the review was to consider the ways in which the use of GMOs in agriculture in the UK and internationally might impact on organic farming. It does not address the controversy about the rights or wrongs of GMO's *per se*. The review is based primarily on evidence from peer-reviewed literature. The review concluded that there was likely to be little impact on organic agriculture in the UK from the use of GMOs in agriculture in the UK or internationally. It acknowledges that there remains scientific uncertainty in several areas. It covered the presence of residual DNA in the soil; in livestock feed; in slurry, manure, compost and mulch; the impact of herbicide tolerant and pest and disease resistant crops; the safety of promoters; and the transfer of DNA in pollen and seeds.

2.5 Organic food – intrinsic quality attributes overview

Cooper et al (2007) provide a comprehensive review of organic food quality issues and the results of recent research in the area. Part 1 provides an introduction to basic quality and safety with chapters on factors affecting the nutritional quality of foods, quality assurance and consumer expectations. Part 2 discusses the primary quality and safety issues related to the production of organic livestock foods including the effects of feeding regimes and husbandry on dairy products, poultry and pork. Further chapters discuss methods to control and reduce infections and parasites in livestock. Part 3 covers the main quality and safety issues concerning the production of organic crop foods, such as agronomic methods used in crop production and their effects on nutritional and sensory quality, as well as their potential health impacts. The final part of the book focuses on assuring quality and safety throughout the food chain, focusing on post-harvest strategies to reduce contamination of food and produce, and ethical issues such as fair trade products. The final chapters conclude by reviewing quality assurance strategies relating to specific organic food sectors.

Benbrook et al (2008) has reviewed the evidence of the nutritional content of organic fruits and vegetables compared to non-organic. Since 1980, 97 papers comparing the nutrient content of organic and nonhave been published in peer reviewed scientific journals (30 have been published in the past five years). Making comparisons between organic and non-organic systems is scientifically difficult because so many complex and interrelated factors must be taken into account when comparing two essentially different systems of production. Consequently there are good and bad points about each of the published studies.

A review by the Soil Association (Heaton, 2001) examined the available research studies and concluded that there were differences between organic and non-organic food in terms of food safety, primary nutrients, secondary nutrients and health outcomes.

Taken overall, the balance of evidence shows that organically produced fruit and vegetables contain more beneficial nutrients than non-organic. There is a high degree of consensus amongst many scientists that vitamin C, iron, magnesium and so called 'phyto-nutrients' like the flavenoids tend to be higher, whilst the dry matter content of organic fruit and vegetables is also generally higher. The higher dry matter content is probably due to the fact that synthetic agro-chemical fertilisers are not used in organic systems, thus the 'nutrient density' of organic fruit and vegetables is greater, consequently there is more nutrient-containing fruit or vegetable and less water.

The Quality Low Input Food (QLIF) EU funded project has examined the product quality of organic farming systems. Lueck et al (2008), summarising the information from research trials and literature review has

concluded that the generally beneficial impact of extensive organic production protocols on the composition of livestock products (meat, milk and eggs) is becoming increasingly clear and the first studies showing positive health impacts of organic milk consumption have recently been published (Rist et al. 2008; Kummeling et al 2008). A more differentiated picture has emerged for crop foods, with **(a)** an overall trend for higher levels of nutritionally desirable compounds being detected in organic compared to conventional foods being confirmed by most studies, but **(b)** certain agronomic practices (e.g. netting to protect crops against pests) being linked to negative effects on specific groups of secondary metabolites.

A recently published dietary intervention study indicated increased immunological responsiveness and robustness in chicken raised on organic diets based on a mixture of grains and legumes (Huber 2007) and effects on body weight and the immune system in rats and mice raised on organic feed stuff (Lauridsen 2007, Finamore 2004). These studies indicate positive trends of organic food consumption and should be explored further in the future. Quality expectations of consumers always radiate around four central concepts **(a)** taste (and other sensory characteristics), **(b)** health, **(c)** convenience, and for some consumers **(d)** process characteristics (e.g. organic production, natural production, animal welfare, GMO-free) (Grunert 2005). To what extent improvements in food composition satisfy consumer preferences and hence their willingness to pay for that improved quality is currently being studied under QLIF.

Although largely out of the control of the farmer and not a quality attribute of the organic farm production system, it is important to note that, in terms of differences between organic and non-organic food as eaten or drunk by the final customer the difference in the content of additives is important. Organic food standards allow only 40 of the 313 additives permitted for use in non-organic food. Although all the additives in non-organic food are controlled by law and can only be used following stringent tests and approval, there remain doubts about the safety of additives. There are reported links between specific additives and disease, health and behavioural problems. There is also evidence that mixtures of additives can have a more potent effect than each additive on its own. Recent Food Standards Agency- funded research found that additives can cause hyperactivity in children. The following additives linked to health and behavioural problems are not permitted in organic food:

- Hydrogenated (trans-) fats
- Phosphoric acid
- Artificial colours and flavours
- Artificial sweeteners
- Monosodium glutamate

Avoiding additives as far as possible is a sensible precautionary approach to reduce the risk of harm and limit the behavioural problems in children that have been associated with some food additives. The best way to avoid additives is to consume fresh and unprocessed food. Where processed food and drink is selected (soft drinks, sweets, snack foods, baked goods etc.), organic processing is preferred since it contains few if any potentially harmful additives.

Huber (2002) reports on the commonly used concept of quality in relation to food, with its emphasis on external appearance and nutritional content, which is not sufficient for organic products and their market. In response a quality concept known as ‘vital quality’ has been developed based on the life processes (growth and differentiation) and corresponding product attributes (vitality, structure and coherence). The research project presented is based on the evaluation of the quality of apples, specifically cultivated for the research project with variation in picking date, bearing, sun exposure, bio-dynamic preparations and ageing after storage. Quality measurements included traditional methods used routinely to assess apple quality and also experimental parameters, which are expected to be relevant for vital quality. Huber concludes that research indicates that as well as the two life processes (growth and differentiation), it is meaningful to consider integration as a third aspect alongside these two processes. Using measurements of the quality of apples grown in particular ways, this work has shown that the experimental parameters appeared to supplement the traditional parameters in a consideration of quality and enrich our vision. The concept of ‘vital quality’ is a

valuable one for the consideration of wider aspects of quality within organic farming systems and should be further developed.

2.6 Food safety

Leifert et al (2008) have reviewed a range of food safety issues that have been raised with respect to organic primary production and processing, including enteric pathogens, mycotoxins and heavy metl and agrochemical residues. The review concludes that there is no evidence that organic and 'low input' production systems pose higher food safety risks than food from conventional systems as claimed by Avery (1998) and Trewavas (2001). In fact agronomic practices used in organic farming were shown repeatedly to reduce risks associated with agrochemical and veterinary medicine, mycotoxin residues and the development of antibiotic resistant pathogenic microorganisms in food. However, it is important to stress that risks can never be excluded 100% at the primary production stage. For example, for poultry meat microbiological safety relies on control measures during processing (heat treatment during cooking), since the complete absence of pathogens such as Campylobacter cannot be assured during primary production, especially under outdoor conditions. It is therefore essential to establish efficient food safety focused quality assurance protocols for both primary production and processing of organic foods.

The potential risk of pathogen transfer to organic produce as a result of management practices including the use of manure has been suggested by Avery (1998) and Trewavas (2001). Fischer-Arndt and Kopke (2007) examined the potential for pathogen transfer by rain splash and mechanical weeding and found no evidence for transfer by these means.

The organic HACCP (Organic HACCP, 2005) project has produced leaflets for consumers, retailers and producers on safety and contamination of organic food. For producers, milk and egg production, cereals, cabbage, tomatoes, apples and grapes are included. These provide practical guidelines to improve quality and safety of organic products.

From the point of view of pesticide residues, organic food production prohibits the use of conventional synthetic pesticides and a only a very limited selection of biological, naturally derived and simple chemical substances are permitted for use. These materials are used infrequently, the most widely used being copper based fungicides on potatoes. Consequently, organic foods are largely free of pesticides, Baker et al (2002) reported that organically grown foods consistently had one-third as many residues as non-organically grown food and one half compared to produce from integrated pest management (IPM) production. Benbrook et al (2008a) has estimated that consuming organic food reduces the risk from consumption of pesticide residues by 97%. The Food Standards Agency (FSA, 2008) acknowledges that "eating organic food is one way to reduce consumption of pesticide residues".

2.7 Crop products – production systems and quality

2.7.1 Cereals and pulses

Mader et al (2007) report on the quality of wheat from the 21-year field experiment comparing conventional, organic and biodynamic production systems and conclude that high wheat quality in organic farming is achievable by lower inputs, thereby safeguarding natural resources. The 71% lower addition of plant-available nitrogen and the reduced input of other means of production to the organic field plots led to 14% lower wheat yields. However, nutritional value (protein content, amino acid composition and mineral and trace element contents) and baking quality were not affected by the farming systems. Despite exclusion of fungicides from the organic production systems, the quantities of mycotoxins detected in wheat grains were low in all systems and did not differ. In food preference tests, as an integrative method, rats significantly preferred organically over conventionally produced wheat.

The UK organic wheat crop, of about 15,000 hectares, is rarely able to consistently provide flour of suitable quality to meet the needs of the baking industry. As a result, more than 50% of the requirement for wheat in the organic bread market is imported. The Better Organic Bread project (Stanley, 2005) seeks to address the constraints to the expansion of the market for organic bread produced from wheat grown in the UK. This will be achieved by identifying the effect of agronomic practices on the protein content and quality of organic wheat. The work will optimise the interaction of raw material characteristics with formulation and processing approaches on bread quality. This will be achieved by establishing the effects of varieties and nitrogen applications in crop husbandry practices on wheat quality. Processing factors during milling and baking, which would improve breadmaking quality and increase the utilisation of UK grown organic wheat, will also be identified. Field trials will be undertaken at 3 sites in the UK over four seasons, they will investigate opportunities for improvement in grain quality by evaluating varieties of spring wheat. The agronomy approaches will include rhizobial inoculation of the fertility building clover crop, use of different rates of high C:N ratio compost, late N application, and optimising the compost formulation. Production protocols will be focussed on creation of stronger and higher quality protein in organic wheat based on the hypothesis that high protein strength can be used to compensate for lower protein content. Ultimately this strategy will lead to increased utilisation of UK organic wheat which has a higher market value in the breadmaking sector. The effect of these approaches on the functional performance of wheat for breadmaking will be quantified. Bread making performance will be optimised by modifications to the milling extraction rate and changes to the formulation of dough mixes and dough preparation procedures. This will provide guidelines for the breadmaking procedures required to obtain dough with appropriate rheological properties for organic bread. These studies will establish and optimise bread production recipes and mixing conditions for organic flours and result in improvements in the quality of organic bread.

Boggini (2007) reports on an ongoing research project in organic cereal farming which aims to guarantee a suitable income to farmers whilst responding to consumers' demand. This project aims to improve the competitiveness on the international cereals' market by innovative high quality varieties and improvement of husbandry techniques maximizing the germoplasm potential. In such a situation a predominant role can be played in Italy by the organic production of cereals with a high technological, nutritional and health quality, in a sector where the demand is also increasing internationally. The overall objective of the project is to increase the technical and scientific knowledge on common and durum organic wheat production and to transfer innovations to organic farmers through: - the identification and/or the development of wheat varieties fitting the specific organic farming requirements, with technological characteristics more closed to the market and consumers' needs, in order both to improve cereal food quality and identify the added value of typical and niche production systems; establishment and refinement of cultural techniques with a low environment impact, looking at those with the best impact on the technological and nutritional quality of the grains (manuring and biotic adversity control). Particular attention will be paid to the health aspect, monitoring the presence of toxic substances in the cereals and their products at the critical points of the production chain; definition of effective methodology for traceability and the control of raw materials and their derived products.

Similar multi-disciplinary work in France (Abecassis et al, 2005) aims to determine the end-use quality along the food chain wheat-flour-bread and to understand how different aspects of quality (technological, organoleptic and nutritional) are delivered. The research project will identify and quantify variability in the end-use quality of organic wheat at the various stages of the production and processing; specification of consumer demand for organic bread to identify main criteria; gather and structure knowledge within the food chain in order to identify new priorities and develop new methods for quality evaluation of organic wheat.

2.7.2 Vegetable market development – the need for quality improvement

The growth in the market and UK supply and imports of organic vegetables has been monitored since 2001 in a series of Defra funded projects coordinated by HDRA in collaboration with the Soil Association, University of Wales Aberystwyth and the Organic Research Centre Elm Farm (HDRA, 2003; Firth et al,

2005; Geen & Firth, 2006). These summaries provide an invaluable guide to the developing organic vegetable market, and illustrate the increasing price pressure that growers are under. This is in part due to the continued desire on the part of retailers to make organic produce available at lower prices, the increasing availability of imported produce at low prices and increasing costs of production. In the more recent market reports, the authors have highlighted the importance for UK growers to compete on quality, placing additional demands on the technical development of systems and skills suitable to UK conditions.

Although a focus on quality through appropriate variety selection and improved production systems is important, the ability of organic growers in the UK to compete successfully with organic growers in exporting countries around the world involves a concerted effort between growers, suppliers and retailers. A detailed assessment of the situation in exporting countries has been made for brassicas and potatoes in a Defra funded project (EcoS, 2007). A commitment on the part of suppliers to UK supply and development is clearly important, but this should be matched by retailers' commitment. Assessment of the production systems revealed that there are differences in the implementation of organic systems in exporting countries which tend to prejudice UK organic producers. This was apparent in the sources of nutrients, rotation and input use in the organic vegetable production systems. Ensuring equivalency of standards will help provide a level playing field between overseas and UK producers, who will then be in a position to compete on quality and provenance, rather than just on price.

Velimirov (2005) compared quality parameters of the same cultivar of carrot grown organically and conventionally in the same region of Austria. Carrots (var. Tarvil) organically grown were significantly preferred by humans and laboratory rats and lost significantly less dry matter during decomposition compared to conventionally produced carrots, although there no consistent differences in the nutrient content.

2.7.3 Vegetable variety selection

Selection of suitable vegetable varieties is an important influence of quality, particularly in organic production since a very limited range of organic acceptable plant protection products are available thus control of pests and diseases through variety selection and good management is extremely important. NIAB have carried out a series of vegetable variety trials from 1997 to 2007 (NIAB, 2001; NIAB 2004) with results published annually. A handbook (NIAB, 2005) summarises the results of over 400 varieties. This is an essential and widely used resource. The results of the most recent series of variety trials (to 2007) have not yet been published. These trials have included organic seed where available as well as untreated conventional seed. The trials also included post-harvest deterioration in simple shelf-life tests (ambient and refrigerated, as appropriate to the normal conditions of sale).

The NIAB variety trials programme for organic vegetables provide important results that help organic growers and advisors select the best variety. From the point of view of vegetable quality, it is particularly important to select varieties with a high level of pest and disease resistance since visual and eating quality, as well as shelf life are considerably affected by the level of pest or disease damage at harvest. Other quality parameters, for example shape and colour, have also been described.

Seed quality is fundamental in the production of a high quality crop, the NIAB (2004) variety trials revealed that seed borne disease can be a particularly severe problem with some carrot and celery seed having significant levels of Alternaria or Septoria infection. In the case of potato, blight resistance is the most important feature, whilst seed should be of a high disease free status, and be well chitted to give better yields of high quality, unblemished 'bold' tubers.

2.7.4 Top fruit - apples

Despite increasing demand for organic apples in recent years, there are few producers of organic fruit in the UK and demand is satisfied largely through imports. Organic apple production in the UK is technically very

difficult and few growers have the confidence to convert to organic production. A Horticulture LINK project coordinated by Garden Organic (HDRA) and involving a wide range of industry and retail partners has studied varieties and integrated pest and disease management programmes for organic apple production (HDRA, 2006). This has focused on developing and evaluating methods for control of key pests and diseases, identification of varieties of apple with low susceptibility to disease with a high fruit quality, storage potential and markets suitable for UK production. Pests and diseases in apples are the biggest technical challenge and are responsible for the loss of quality (and yield) in organic apple production. A practical guide for organic apple production has been published (HDRA, 2001a) as part of a Defra funded knowledge transfer project (HDRA, 2001c).

Fruit quality was evaluated to select and test the consistency of quality of each fruit variety and storage trials were also carried out in both basic air storage regimes and subsequently in a basic CA (Controlled Atmosphere) regime. Large-scale consumer taste tests were completed to evaluate a final selection of eleven dessert apple varieties which had been selected as 'most promising' over the previous four years of assessment. Detailed information of the performance and quality of each of the apple varieties is provided (HDRA, 2006), which can be used to select the most appropriate varieties from the point of view of quality and pest and disease resistance.

An earlier HDRA project (Bevan and Lennartsson, 1999), reviewing knowledge on organic apple and pear production revealed that organic growers have problems with their fruit not reaching the high standards expected from the supermarkets. Although it was noted that supermarkets are more sympathetic towards allowing a lower cosmetic appearance in organic fruit, but growers still fear that standards will become more stringent once they have started to supply. It is important that realistic standards are set which are both acceptable to consumers and achievable using organic growing methods. Major characteristics to consider are fruit size, pest and disease blemishes, russetting and firmness. Different varieties may need different standards. Ideally this standard should be set for a number of years so that every one concerned knows the target.

2.7.5 Soft fruit

Although there is strong demand for organic soft fruit in the UK, especially from processors, these crops are grown on a very small scale in the UK and supply is met largely through imports. A practical guide for organic strawberry production has been published (HDRA, 2001b) as part of a Defra funded knowledge transfer project (HDRA, 2001c). Practical grower guides have also been produced on cane fruit (Cubison, 2006) and bush fruit (Cubison 2006a). The major problem identified in organic production of soft fruit (strawberry, raspberry, blackcurrant and gooseberry) was weed control (HDRA, 2001c and Bevan & Lenartsson, 1999), which has a significant impact on the financial performance of the production system, it does not affect the final quality. However, pest and disease control is important and the grower guides provide information on the control of the key pest and diseases in organic soft fruit production. Successful pest and disease control is essential for acceptable yields of quality crops.

2.7.6 Storage and shelf life of organic fruit and vegetables

Shelf life of organic vegetables has been studied in a MAFF funded project (NIAB, 2002) to investigate whether the potentially higher pest and disease loads of organic produce affect shelf life. Several varieties of organically grown vegetables (carrots, broccoli, lettuce, novelty salads, parsnips and potatoes) were stored under a range of temperature, humidity and light conditions to determine the maximum shelf life. The results provide a useful source of advice to organic growers on the most appropriate varieties for cost effective production and presentation of high quality organic produce.

Olmez et al (2007) report on trials to test the efficacy of alternatives to chlorine for sanitization of fresh cut lettuce stored at 4^{O}C. Ozonated water treatment was compared with a organic acids (citric plus ascorbic), a permitted treatment for sanitization of organic produce, and chlorine washes (not permitted in organic and in

some EU countries not permitted for conventional products). Ozonated water was observed to be as effective as chorine and organic acid washes.

Weibel et al (2007) review the strategies for improving shelf life of fruit from organic production systems.

2.7.7 Nutrient supply strategies effect on crop quality

Kjellenberg and Grandstedt (2005) report on a long term 33 year (1958 – 1990) comparative fertilization trial carried out by the Scandinavian Research Circle for Biodynamic Agriculture. The trial ended in 1990. From the point of view of crop quality, the manure and compost treatments yielded crops with better storage which resisted decomposition, and the maturity of the crops was enhanced.

Rattler et al (2005) studied the effect of different sources of nitrogen on lettuce quality and observed that lettuce treated with mineral nitrogen fertiliser (calcium ammonium nitrate) displayed a higher nitrate content than lettuce treated with organic manures , although nitrate concentration tended to increase with increasing amounts of fertiliser, independent of fertiliser type. Rapidly available nitrogen from mineral fertiliser gave higher lutein levels compared with slowly released nitrogen. Similar results were observed for ß-carotene. There were no obvious differences regarding polyphenols for the different modes of fertiliser input.

Neuhoff et al (1999) reports on the effects of different intensity and kind of manuring between organic and biodynamic agriculture. Biodynamic preparations are supposed to improve plant growth and food quality, minimising natural variations. This paper deals with investigations of influences of these preparations and increased manure application on potato yield and tuber quality. Only two significant differences between organic and biodynamic manuring were detected. The significant increase of tuber yield in the biodynamic treatment agrees with other results by Neuhoff et al (slightly higher tuber yields in the biodynamic treatment) and those reported by Lücke and v. Boguslawski (1982). The higher tuber potassium content detected once in the organic treatment cannot be explained. Lower nitrate and higher dry matter contents in the biodynamic treatment were found only in the Darmstadt trials. Although present data show a small positive impact on yield and tuber quality, a clear advantage of using the biodynamic preparations cannot be established from these results. The effects of manuring on yield were stronger on the sandy soil (Darmstadt), with low soil nitrogen content and high mineralisation rate of manure. In the Wiesengut trial, with its higher soil nitrogen content (preceding crop: grass/clover mixture), manuring affected tuber yield only slightly. Plant uptake and content of potassium was largely improved by manuring, whereas negative effects (decreasing dry matter content, slightly increasing nitrate content) were not very pronounced. Therefore the amount of manure applied should be based on optimal shoot growth and sufficient potassium supply, thus promoting tuber yield and quality.

2.8 Livestock products – production systems and quality

2.8.1 Dairy

The composition of milk is affected by the production system, with organic production leading to higher levels of short chain essential Omega-3 fatty acids in milk (Ellis et al, 2006). This increase is primarily associated with the greater intake of clover based forage in the diet, and this has been observed in conventional dairy systems (Dewhurst et al, 2003) as well as organic, although it is important to note that the use of a largely forage legume based diet is a requirement in organic standards, thus the elevated levels of Omega-3 fatty acids would be expected to be consistently higher in organic as compared to non-organic milk.

Ellis et al (2006) reports the effect of various aspects of the production system on the level of Omega-3 Alpha Linolenic fatty acid (ALA)in milk, with the use of Holstein/Friesian breeds being associated with lower levels, compared to other (mixed) breeds; lower yields being associated with higher levels of Omega-3 and the use of total mixed rations (TMR) tending to lead to lower levels of the fatty acid. These system

differences support the view that the use of organic appropriate breeds and feeding strategies tend to result in milk with a better nutritional properties compared to more intensive organic dairy production systems.

Butler et al (2007) compared the fatty acid profiles and levels of fat soluble antioxidants in milk from organic and conventional production systems in five European countries (Wales, England, Denmark, Sweden and Italy) and confirms the observations of Ellis et al (2006) with regard to Omega-3 ALA. They also observed that vaccenic acid and Conjugated Linoleic Acid (CLA) were higher in organic milk than conventional. They noted, when comparing feeding strategies between the European countries, that the use of maize silage (not common on organic farms in the UK) resulted in lower levels of nutritionally desirable fatty acids and antioxidants in organic milk compared to that conventionally produced.

The use of antibiotics for control of mastitis is permitted in organic dairy systems, although not on a routine or prophylactic basis. This results in lower use of antibiotics in organic dairy farms (although there is a large difference between farms) however, the incidence of mastitis is similar (SAC, 2007; VEERU, 2000). The use of antibiotics in organic dairying has an impact on the quality of the milk, both as a cause of potential contamination of the milk and as a risk factor in reducing the efficacy of antibiotics in human medicine. Thus there is a need to reduce reliance on antibiotic use, and many organic farmers successfully operate with low levels of mastitis and zero or minimal antibiotic use. Alternative strategies for mastitis control including best management practice and alternative treatments have been reviewed in a Defra funded project (VEERU, 2000). The efficacy of homeopathic nosodes (preparations made from the disease organism and used on a herd basis as a preventive treatment) have been studied in a further Defra funded project (University of Bristol, 2000). No significant effect on mastitis incidence was observed.

University of Wales (2007) reports on an ongoing project aimed at minimizing medicine use in organic dairy herd. The project aims to develop animal health and welfare planning principles for organic dairy farms under diverse conditions based on an evaluation of current experiences; improve application of animal health and welfare assessment based on the Welfare Quality parameters in different types of organic dairy herds across Europe. Including the development of a special system for calves; develop guidelines for communication about animal health and welfare promotion in different settings.

2.8.2 Beef and sheep meat

Grazing beef cattle and sheep on pastures with a wide range of species has been shown to improve the quality of the meat produced, with enhanced flavour and fat composition (RELU, 2008). The research project investigated the benefits of grazing livestock on natural grassland on product quality and linked this to the impact on farm business performance, ecological management and human health. Although the research was not focused on organic systems, the results are directly relevant to organic management since the lower intensity and the marketing opportunities are directly linked. However, the more seasonal production and limited availability of abattoirs and meat processing facilities mean that producers with smaller volumes can be disadvantaged, and producers are more likely to have to resort to direct sales due to the difficulty of accessing volume outlets, for example through supermarkets.

Chemical analysis of the products, as well as tasting panels and consumer focus groups showed that meat products from animals grazed on biodiverse grassland showed a number of positive characteristics. This research has implications for organic production and suggests that organic farmers should focus, where possible, on the use of diverse, natural swards where these are available to graze their livestock and then promote the potential for the greater quality of the meat produced. Lamb meat produce on biodiverse rich grassland (particularly heather rich pasture systems) had higher levels of vitamin E, and had lower levels of skatole (skatole can adversely affect meat odour, particularly during cooking). The meat also contained higher levels of nutritionally healthy fatty acids. Beef from Longhorn cattle also contained significantly higher levels of 'beneficial' fatty acids. Results from taste panels demonstrated that breeds like the Longhorn, more suited to grazing biodiverse, natural pastures generally yielded more tender and intensely flavoured meat. It is also important to note that extensive grazing systems play a key role in maintaining

habitats and managing extensive, natural grassland, consequently farmers using these pastures for livestock production can help maintain and protect threatened and marginal ecosystems.

2.8.3 Pork

Kelly et al (2007) reports on Defra funded trials on the effect of breed, housing and feeding systems on the performance and quality of organically reared pigs. Carcass fatness was lowest for 'modern' breed (Camborough 12), highest for the 'traditional' purebred Saddleback and intermediate for the 'crossbred traditional' genotype (Saddleback x Duroc). When the production systems were compared, growing pigs at pasture had a higher killing-out % but similar carcass fatness. The Defra project also reviewed the raw materials for feeding organic pigs and makes recommendations for feeding to achieve best quality and growth rates (Edwards, 2002) and published a guide to good practice for organic pig production (Martins et al, 2002).

Sundrum (2005) has assessed production systems and quality of organic pork and concluded that most of the assessed carcasses of organic pigs did not meet conventional standards in relation to carcass yield, meat quality and in relation to the intramuscular fat content, although there was huge variation of quality traits between farms, which presents a challenge for the organic market. These results are similar to those reported by Jonsäll et al. (2002), who found organic pork quality to be inferior compared to conventionally reared pork. Pork loins were found to be less juicy and gave higher scores for crumbliness when tested by a trained taste panel. Sundrum (2005) concludes market and consumer expectations of high and uniform quality traits of organic pork do not appear to be met. However, he considers that the diets based on grain and pulses do have the potential to produce pork with a high intramuscular fat content: a precondition of a high sensorial quality.

2.8.4 Poultry meat

The minimum age at slaughter for organic poultry for meat production is likely to lead to a more intense flavour a feature that is thought to be expected by consumers of organic poultry. In a detailed MAFF funded review on poultry meat quality in extensive production systems, Gordon (2000) reports results of trials that demonstrated that breast and thigh meat flavours were more intense in birds slaughtered after 54 days (similar to conventional free range systems) than at day 34 (typical for intensive broiler systems). Thus it would be expected that the even longer growing period required for organic chicken meat would be expected to further emphasise this taste difference.

Castellini et al (2002) completed a comparative trial between chicken reared organically and conventionally and reported that the organic chicken contained higher levels of polyunsaturated fatty acids, including 38% more omega-3, than the non-organic chicken. It also found that the free-range behaviour of organic chickens reduced abdominal fat by 65% and favoured muscle development. Taste tests found that the organic chicken scored significantly higher for juiciness. In contrast a much smaller study, where a small (a total of nine samples including organic and non-organic free range and intensive samples of breast meat) number of uncontrolled samples were purchased from a supermarket in Scotland (rather than being reared in controlled conditions), reported that the organic chicken was less tasty and had a poorer nutritional profile (Lahon et al, 2006). This study was widely reported (e.g. MacRae, 2006), but on closer examination, the conclusions drawn were based on very limited evidence.

From the point of view of carcass conformation, there has been a very successful focus by poultry breeders to select for breast meat yield, whilst also selecting for high growth rates and low feed conversion ratios. The high growth rates of modern breeds can present a problem when they are used in organic poultry production systems with a minimum slaughter age of 81 days since there is a risk that the birds get larger than is the optimum for market requirements (around 2kg), requiring restriction on feed intake and consequently potential welfare implications for the birds. According to the Defra funded research (ADAS, 2003) dark meat makes up a larger proportion of the total edible meat in extensively reared chickens compared to non-

organic intensively reared broilers. This research has identified the need to select breeds with an appropriate growth profile to overcome the problems of high growth
rates of the rapid growing breeds for intensive production. In the field trials (ADAS, 2003) the impact of breed on flavour was studied in detail, and although there were only small differences across all the breeds studied, the very slow growing breeds tended to have slightly better flavour scores.

The research also noted the importance of selecting breeds that have a propensity to range. Detailed studies of the usage of pasture by the growing birds demonstrated differences between breeds concluded that pasture use (which is likely to affect flavour through ingestion of grass and other plants as well as invertebrate fauna) is encouraged by providing access to pasture in early life (although rotation of pasture is essential to avoid build up of parasites). Providing simple movable shelters on range can encourage wider ranging and thus more even pasture usage.

3. Analysis and Conclusions

3.1 Scope for farmer control of food quality

The review has revealed a large number of approaches to enhancing food quality that are within the farmer's control including the design of the farming system, nutrient supply regimes for crop production, selection of appropriate breeds and varieties and livestock feeding strategies

3.2 Wider quality attributes of organic food important

The environmental, biodiversity, pollution reduction, animal welfare and social benefits of organic farming all represent system quality benefits which are extrinsic. Other extrinsic public health benefits also may arise from organic farming and food: there is less pesticide and nitrate in water; residents and bystanders are not subjected to diffuse pollution from chemical spray drift and organic farming limits climate change. The focus of this review are the intrinsic benefits, both from the point of view taste or hedonistic quality and from the point of view of potential individual human health benefits due to the following putative differences between organic and non-organically produced food:

- Fewer additives
- More beneficial nutrients
- Less pesticides used and conventional synthetic pesticides are prohibited
- Less veterinary drugs, particularly antibiotics are used and some are prohibited
- Genetically modified organisms are prohibited

3.3 Impact on human health

The impact of organic food consumption on human health is a key issue from the point of view of the consumer. Health outcomes from consuming organic food will depend firstly on the quantum of any or all of the intrinsic quality parameters in organic compared to non-organic food (for example quantity of nutrient or pesticide residues etc) and secondly on the physiological or biological effect arising from this difference (if any). Measuring positive or negative health outcomes as a result of, for example, the additional nutrients or lesser amount of anti-nutritive substances (e.g. pesticide residues) is obviously difficult. Few studies have been carried out in humans, whilst some animal studies have been completed.

Many food scientists consider that the likely impact of the difference (if any) between organic and non-organic food are negligible compared to the importance of a diet that contains a large quantity of fresh and unprocessed vegetable based food with moderate quantities of meat and dairy products and as little highly processed food as possible. In the case of highly processed food, it is important to draw a distinction between modern processing methods, creating 'junk food', for example white bread, white sugar, 'fast-food'

and so on and traditional processing like cheese making, meat curing, yoghurt. Although traditional processing may involve the addition of sugars (in jam) or salt (in cured meats), it would seem likely that these are less hazardous than more modern junk food. This is a potentially contentious point.

3.4 Methodology

There are difficulties with methodology when one attempts to make system comparisons. Depending on where the 'system boundary' is drawn, it can be claimed that the organic system is essentially irreducible to an experimental plot in a replicated, randomised field trial. If this is true, then attempts to use normal scientific methods to determine differences is likely to be fraught with irresolvable problems. A number of alternative (so-called 'holistic') methods for quality determination have been developed over the past 40 years, but the validity of these is contested by many food scientists, whilst the relationship between the parameters measured and the intrinsic qualities that may influence human health or taste are not obvious.

The selection of small numbers of samples from point of sale can lead to confusing and incorrect results, for example, in December 2006 a news report (MacRae, 2006) of results from a study on organic and conventional chicken breast samples stated that "Organic chicken even fared poorly in blind taste tests, gaining the lowest marks for succulence". This news report arose from a paper (Jahan et al, 2006) that on investigation included a very small number of uncontrolled samples purchased from a supermarket. Consequently the conclusions drawn were more than this research could support.

3.5 Novel food quality concepts and methodologies

Holistic methods – Velimirov (2005) demonstrated the superiority of organic carrots using holistic methods. Carrots produced organically had lower P-values, indicating better bioelectrical properties, revealed a significantly better capacity to store biophotons. In this trial, the holistic methods for quality determination were able to distinguish organic from conventional carrots.

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